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ABSTRACT

An Eisenhower-funded science improvement project with activities endorsed by American Association for the Advancement of Science (AAAS) and National Science Teachers Association (NSTA), including science as inquiry and technology integration, was conducted by Valdosta State University (VSU) for four years in four Georgia Counties. Positive results led the Florida Department of Education to contract with VSU to implement similar professional development strategies in Florida. The project included: (1) Involvement of all science teachers within a system; (2) extensive contact time and long-term follow-up; (3) inquiry- based teaching orientation; (4) technology integration. All of the above was incorporated in a needs and site-based format. The initial weeklong meeting was followed with Saturday sessions for eight weeks. Participant responses indicated overwhelming support and student success. Case studies of two participating schools present a view of the change process from teachers' and students' perspectives. (Author)

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INQUIRY SCIENCE AND TECHNOLOGY INTEGRATION PROJECT: A VIEW OF TEACHER CHANGE

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An Eisenhower-funded science improvement project with activities endorsed by AAAS and NSTA, including science as inquiry and technology integration, was conducted by Valdosta State University for four years in four Georgia counties. Positive results led the Florida DOE to contract with VSU to implement similar professional development strategies in Florida. The project included: (1) involvement of all science teachers within a system; (2) extensive contact time and long-term follow-up; (3) inquiry-based teaching orientation; (4) technology integration. All of the above was incorporated in a needs and site-based format. The initial weeklong meeting was followed with Saturday sessions for eight weeks. Participant responses indicated overwhelming support and student success. Case studies of two participating schools present a view of the change process from teachers' and students' perspectives.

A View of Teacher Change

I watched her walk into the library, arms crossed, a scowl on her face, carrying a McDonald's breakfast. As she set the bag down on a table, greeting fellow workers, Ginny avoided eye contact with any of the project staff. After a few bites of her breakfast, she jumped up and ran to the door, as if she had forgotten something. Ginny reminded me of my students who came to class but were not ready to commit to taking their seat and starting to work. There was always "just one more thing" for them to do somewhere else other than biology class. In a few minutes Ginny returned and as she re-entered the library I heard her comment to a co-worker: "One more thing we don't have time for."

This will be a hard sell, I thought. Ginny was moving to a self-contained classroom for the first time, and although she would continue to teach 5th grade, she would be teaching science for the first time in many years. Previously, she had taught language arts. Top that off with a new building, texts, technology, and standards. It *was* "just one more thing."

I returned in 6 weeks to find a new Ginny. In her own words, she was energized by the inquiry method. Two weeks earlier, a project staff member had helped Ginny design an inquiry lesson about rocks. The first step was to take her students outside and just look for rocks. The

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students brought rocks back to class and collaborated to classify their specimens. Ginny noted that this experience offered many opportunities to branch out into other areas of student interest. One girl found a rock containing shells and a discussion of Florida geography followed. Children shared rocks from home, from trips to other geographic locations. They wrote stories, practiced self-evaluation, involved their parents, and as one boy stated: "took an exciting adventure."

What precipitated this change in classroom practices and teacher beliefs? That is the question this paper examines as we take a look into the change process among science teachers in two school systems after participating in an inquiry and technology based staff development project.

Introduction

In recent years, academic deficiencies of U. S. science students have been of primary concern to both the U. S. Department of Education [1] and the National Research Council (NRC) [2]. Significant reform efforts have characterized U. S. science education since 1947 such as those stimulated by Sputnik in 1957 and the National Education Goals, a result of the Governor's summit of 1990 [3] (NSF). Student science achievement increased for two decades until the mid-1970's, but since then has held steady. Many students leave high school without a strong science or mathematics foundation, and black and Hispanic students continue to perform below their white counterparts.

According to former U. S. Secretary of Education Richard W. Riley although science achievement has experienced gains, there is room for improvement. Riley stressed the need for improved professional development for K–12 science teachers as well as recruiting more science teachers [4]. The Third Mathematics and Science Study – Repeat (TIMMS-R), which examined mathematics and science achievement, schooling, curricula, instruction, and the lives of teachers and students from 38 nations, reported little improvement in the performance of U. S. eighth-graders in mathematics or science since 1995. The TIMMS-R noted that U. S. students were more likely than students in other nations to be taught by science teachers who majored in education rather than by teachers with a college major in any science field.

In February, 2000, U. S. students were administered the National Assessment of Educational Progress (NEAP) in science and only recently, Georgia State School Superintendent Linda Schrenko released science scores for grades four, eight, and twelve [5]. Although Georgia's scores were higher than other states in the southeast, they were lower than the nation, with 48% of Georgia students scoring in the "below basic" range. "Basic" level denotes partial mastery of prerequisite knowledge and skills for each grade level tested. Additionally, 67% of African American and 56% of Hispanic students in Georgia scored "below basic".

In response to these national and state reports, improved science teaching and learning have been the focus of professional development efforts throughout the country. Within this context a team of professors at Valdosta State University (VSU) conceived a needs- and site-based inquiry and technology professional development plan for teachers in South Georgia schools. VSU's service area contains a high proportion of minorities, as well as students from economically disadvantaged families, and South Georgia student performance on the state

mandated science assessments were well below achievement levels in the other three academic areas [7]. As a regional university of the University of Georgia system, it is VSU's mission to fulfill the academic needs of South Georgia. Therefore, VSU must reach out to science teachers in the area to improve teaching skills if students are to become productive, contributing members of the local communities [8].

The VSU inquiry-technology project, which began in 1998 and has been implemented in four area school systems, was designed to improve science classroom instruction in South Georgia by assisting teachers to (1) become knowledgeable and proficient with inquiry-based teaching and (2) obtain the necessary skills to incorporate instructional technologies into an inquiry format [9]. A striking departure from the science classroom norm, constructivist theory and science as inquiry dictates that knowledge and understanding must be (1) actively acquired; (2) socially constructed; and (3) created and recreated for individualized meaning [6] and logically, teachers would require substantive support and education to understand, accept, and master such techniques.

Most recently, a partnership began with inquiries from a science educator at VSU to the Florida Department of Education. The discussions involved how best to assist a neighboring school district that happened to be across state lines. Personnel from the Florida DOE became interested in transporting a successful science teacher professional development model used in South Georgia to districts in their state. A unique cross-state, cross-institutional partnership, supported by the Florida Department of Education, emerged as a result of these discussions.

The Florida LIST Project, lead by VSU faculty, was delivered in a north Florida district and served as a vehicle to "train the trainer". Faculty members from the University of North Florida were educated as to the format of the LIST Project as VSU faculty and area master teachers modeled the planning and implementation techniques of the project. The goal is that in subsequent years, UNF faculty will deliver the LIST Project in their region thus increasing standards-based science instruction in rural, high minority districts in north Florida.

Project Participants

Georgia participants included 12 secondary and middle school science teachers from Ben Hill County. Additionally, both the system curriculum director assisted in the planning phase and a reading specialist participated in both the project planning and implementation. Teachers represented a range of 1 to 39 years teaching experience.

Florida participants included 19 teachers representing grades 4 – 9 and a range of 2 to 31 years teaching experience. A liaison from the central office also participated in the project. Florida teachers reported substantial anxiety as the 2001-2002 school year approached because their previously familiar teaching environment was in a state of transformation. Teachers in grades K – 8 would be in one school and many of the participants awaited new teaching assignments, the move to a self-contained classroom, textbooks and technology not previously utilized, and the incorporation new state science standards.

General Project Procedures

I. Exploration Phase

For a period of one week in the summer of 2001, the teachers met for five days from 9 a.m. to 3 p.m. on-site of a participating school. During the first one and a half hours of each day, teachers met in seminar sessions. These seminars, led by the science education professor, were devoted to examining (a) the structure of science, (b) the nature of human learning, and (c) authentic assessment strategies for student evaluation in learning cycle curricula. The remainder of each day was spent in two laboratory sessions led by other members of the project team, scientist, education technologist, and Teacher Support Specialist. These sessions included technology laboratories, designed to familiarize teachers with the use of a variety of educational technologies and how to incorporate these into their curricula as well as science laboratories modeling the learning cycle teaching procedure led by in-service middle school and high school teachers experienced in the inquiry teaching procedure. This phase of the project required teachers to meet with project staff at least 30 hours over the five-day period.

A significant aspect of this project is that four in-service science teachers from neighboring counties assisted in making learning cycle presentations and sharing their experiences. The involvement of these past participants further facilitates their professional development, reinforcing and expanding their knowledge of the learning cycle and technology integration.

An important point to be made here is that each learning cycle investigates important and easily recognizable scientific concept(s). That fact permits the teachers in the workshop to review science content while they learn how to teach that content using learning cycles. A scientist is on staff to monitor the accuracy of the science content taught through the learning cycle demonstrations and act as a science content reference for the remainder of the staff and teacher participants.

II. Application Phase

This phase began after the first two weeks of the start of school in August 2001. Teacher participants met with the project staff every alternate Saturday for 8 weeks from 10a.m. to 3p.m.; four total sessions over an eight-week period. These meetings took place in teachers' classrooms and the technology lab.

During the Application Phase, teachers received a copy of the learning cycle science curriculum, and in partnership with each other and the project staff, modified two weeks of current science curriculum into inquiry-based lessons. Successes and difficulties of implementation were discussed on a regular basis. This phase of the project required teachers to meet with project staff at least 20 hours over the four meeting days. Additional communication with staff members, such as the scientist for questions pertaining to content, was encouraged through the use of electronic mail.

III. Follow Up Phase

The Follow Up Phase occurred through the remainder of the fall semester. The Exploration and Application Phases of the project allowed teachers to accommodate the inquiry

based curricula and its theory base; but sound understanding comes with using the learning cycle in their science classrooms during the ensuing school year. Therefore, follow up communication and feedback was a significant part of the project proposed here and occurred in several forms.

A member of the project staff periodically observed teachers in their classroom during the school year. Following each observation will be an individual meeting between the teacher and staff member to discuss the implementation of the inquiry teaching procedure, incorporation of technology, assessment, or other factors associated with the curricula. Project staff reviewed sample lesson plans and reflective writings were collected.

It is estimated that the follow up part of this project will result in at least 12 hours of contact time between each participant and the project staff. Total contact time with each teacher over the course of the project will be at least 60 hours. Teachers will receive six SDU credits and a stipend of $100 for participation in this project.

Site Specific Procedures

The LIST Project's needs- and site-based plan was based on professional development literature, incorporating The National Partnership for Excellence and Accountability in Teaching [9] recommendations that effective professional development for teachers should be: (1) focused on what students are to learn, encompassing site-specific content goals; (2) based on analyses of differences between actual student performance and goals and standards for learning; (3) designed to involve teachers in the identification of what they need to learn and in the development of the learning experiences in which they will be involved; (4) school-based. The project took place on-site, teachers were involved in the initial and continual planning of activities, and such activities were based on the needs of the students in that system and the resources available. Although an advisory panel composed of university faculty, master teachers, and system personnel did the preliminary planning, such planning was based on the expressed needs of the participatory teachers and they themselves quickly became an integral part of the collaborative process that drove the project. During the initial phase of the project, the constructivist/inquiry approach to teaching was discussed, VSU staff modeled an inquiry format as teaching strategies were presented, and teachers learned inquiry by doing inquiry with site-specific texts and appropriate technology. In the second phase, evolving needs and problems of the participants were addressed in follow-up sessions that continued for 10 weeks.

GEORGIA

Mandated by the state, middle school teachers were required to have 50 hours of reading staff development during the summer of 2001. In light of this, a reading specialist was added to the staff and requisite contact hours were incorporated into the project plan. The observation checklist was modified to include evaluation of reading strategies implemented in the middle school science classroom.

Technology instruction took place in computer labs at the middle and high school, thereby allowing teachers to utilize equipment and technology unique to their individual settings. The system's technology specialist was on-hand to familiarize the participants with new technological developments installed during the summer, 2001.

FLORIDA

The north Florida teachers, grades 4 – 8, were in a state of transition. About to move into a new pre-K – 8th grade school, many of them would be teaching science for the first time in many years. Most of them were moving back to a self-contained classroom, and all of them would be using new textbooks and learning how to operate the new technology on-site. Several were fledgling teachers, with only 2 years of teaching experience.

Additionally, accountability had taken a front seat in Florida and teachers were required by the state to teach the Sunshine State Standards. The Standards, approved in 1996, were written in seven subject areas, each divided into four separate grade clusters (PreK-2, 3-5, 6-8, and 9-12). As Florida moved toward greater accountability for student achievement at each grade level, the Sunshine State Standards were further defined. In the subject areas of language arts, mathematics, science, and social studies, the Sunshine State Standards were expanded to include Grade Level Expectations. These Grade Level Expectations will eventually become the basis for state assessments at each grade 3-10.

The Florida Comprehensive Assessment Test (FCAT) is part of Florida's effort to improve the teaching and learning of higher educational standards. The primary purpose of the FCAT is to assess student achievement of the high-order cognitive skills represented in the Sunshine State Standards (SSS) in Reading, Writing, and Mathematics. The SSS portion of FCAT is a criterion-referenced test. A secondary purpose is to compare the performance of Florida students to the performance of students across the nation using a norm-referenced test. All students in Grades 3-10 take the FCAT in the spring of each year.

Scheduling concerns at the elementary school redirected project staff efforts during the Saturday sessions. Teachers in grades 4 – 6 taught science for three weeks during a six-week time period. To maximize student contact time, teachers requested information regarding learning centers so students might work independently on a science topic when they had spare class time. Although not a topic previously covered by the workshop, the Saturday sessions were redesigned to include examples of appropriate learning centers tied to the Florida standards.

To summarize, the Florida participants were in a new school, teaching new classes, using new materials, and facing a new set of teaching and learning standards and assessments. University of North Florida participants provided valuable resources to address these issues of accountability.

Base-line Data

Self-report questionnaires surveyed participants about classroom practices and technology skills prior to implementation. This information was used to establish a baseline in inquiry approaches to teaching, technology skills and integration, and alternative assessment techniques. Descriptive statistics report entry participant practices and skills.

Prior to the project, methodology, though varied, would be classified as traditional. Teacher lectures, student reading, and worksheet completion accounted for 41.6 % and 44.1% of the classroom teaching methods used in participating Georgia and Florida schools, respectively,

One might expect a higher percent of laboratory time in the Georgia school due to the predominance of high school teachers in the sample. Of these teachers, only one indicated the use of inquiry-based labs prior to the professional development.

A Likert scale survey was used to determine who directed classroom instruction, teachers or students. A traditional science classroom would be teacher-directed, while in an inquiry environment, the learning would be student directed. The response scale ranged from 1 to 7 with "1" representing teacher directed, "4" representing teacher and student direction equally shared, and "7" representing student directed. Survey data indicated a traditional approach to classroom teaching and direction.

To better address the specific technology needs of the participants, teachers were given a technology skills survey. Technology usage was limited. The three most common technologies utilized in both systems were the computer, video/VCR, and television. Additional free responses indicated a high level of anxiety for technology utilization in the science classroom. However, when asked how receptive they would be to learning how to use new software or technologies, all but two teachers responded that they would (1) look forward to learning a new skill or (2) feel apprehensive but try it anyway.

Survey data indicated a varied selection of evaluative techniques, with the noticeable absence of performance-based assessments.

Workshop Evaluation

Evaluative data collected via post-workshop surveys indicated overwhelming teacher support of both the project and pedagogy. Responses to the open-ended comment items included such descriptors as great/good workshop, great information, inspirational, reminder to make science exciting, empowering, interesting. Teachers in both systems noted that active, inquiry techniques are a wonderful teaching/learning tool for the poor reader, in that they could see and experience science as well as respond verbally to their peers and instructor. In the words of another participant:

> Expert presentations have provided great ideas and methods for implementation. This is key! Sometimes you know what to do, but not always the best and easiest way to do it. The workshop has provided opportunities for me to "walk through" becoming familiar with the unfamiliar.

Negative responses focused on insufficient time and classroom resources to allow for implementation of either lab activities or technology in the science classroom.

Participants completed another evaluation questionnaire at the last Saturday session. All teachers responding described the Saturday sessions as useful, exceptional, and informative, presenters were described as very knowledgeable, and participants noted the importance of being permitted time to collaborate and compare notes with master teachers and their peers. Although some teachers noted he need for more materials and additional technological resources, most responded by emphasizing the importance of personal interaction with the project staff. They stated that on-going staff support, which includes new ideas, brainstorming, and just periodic encouragement, was critical to their continued success.

Charting Change

Self-report surveys, participant written reflections, and analysis of lesson plans were utilized to analyze change in classroom practices and technology skills during the past four months. In addition student pre and post-test scores were collected and a statistical test was computed to determine significance of differences in student performance.

In their written reflections, teachers reported on their level of comfort trying new strategies. They commented on both incorporating inquiry and technology into science lessons, and noted, as time passed and they continued to implement new activities, their comfort level rose. Teachers used words like empowered, energized, and motivated to describe their feelings about teaching science: "As the children's excitement grew, so did mine. They pushed me out of my rut." One teacher commented that she is no longer a "page-by-page" teacher.

Responses regarding student reactions to inquiry were extremely positive, providing descriptions that included:

- student excitement for inquiry activities
- greater student interest in science topics
- involvement of all students
- opportunities for non-readers to excel
- students take charge of their own learning.

For some teachers it was a giant step to put students in cooperative groups, overlook the noise, and let students discover for themselves: "It was hard to sit back and let the children do most of the work. After you see how much they learn, it gets easier." Another teacher commented on how the "new chaos" in her classroom allowed her to "float around and really facilitate student learning."

Not only were students excited and motivated, and in all, they had fewer discipline problems. Said one 5th grade teacher: "Joe Cool works well with hands-on activities. His behavior is much better when his mind and his hands are set on the activity or center." The inquiry activities have also opened new doors for non-readers: "One of my non-readers brought extra rocks of various textures. He found rocks like them in the books in the reading center. I read the names and he labeled them correctly.

Finally, student pre and post-test scores indicated a significant improvement. The average mean difference in test scores was + 45.4 points for grades 4 – 6, + 42.1 for grades 7 and 8, and +38.6 for grades 9 – 11.

One veteran teacher, initially hesitant, but ultimately supportive of the inquiry approach, analyzed the change effort in this manner:

> We have been in school for only three weeks. In addition, we are adjusting to not only a brand new building but to the consolidation of four different county

schools. We are also teaching from brand new materials based on the Sunshine State Standards and geared to an inquiry method of teaching. With all of those changes present, it is difficult for me to relate any reactions in my class to one particular aspect of the classroom environment.

What I am discovering is that students, as a whole, love gimmicky things such as passing sealed butter tubs around and asking then to write down the number of objects inside, to describe them, and to draw them. This was used, with follow-through questions, to introduce them to the difficulty of studying things we cannot see such as the atom. Even my lower ability students understood the point we were trying to make and, on reviewing, were still able to make connections.

Promoting Success

Professional development should involve the participants in the identification of what they need to learn and if possible, in the development of the process to be used [8]. Such engagement increases motivation and commitment [9], enhances efficacy, empowers teachers to take risks and assume new roles, and makes the school culture more collaborative and improvement oriented [10]. Indeed, the needs of teachers in both systems determined the content, to a great degree, of the professional development. Teachers in Florida requested help with new texts and resource materials, as well as state mandated standards and assessments. When it became apparent that time did not allow for daily science lessons ("With only 3 weeks per grading period to teach science, we have to fit in as much information as possible."), project staff and classroom teachers collaborated on the idea of developing science centers aligned with requisite curriculum standards to supplement group activities.

Although site-based, the professional development should provide ideas and knowledge from external sources while facilitating the evolution of new pedagogy [11]. Deep learning and change in pedagogy takes time, including time to establish trust and shared meaning, which according to Hodges [9], can take from three to five years. The Ben Hill teachers joined together in a collaborative effort to build a base of support for inquiry pedagogy. Of the twelve teachers involved in the project, three were already inquiry converts and their enthusiasm and support served as a steppingstone for the others. The same was true of technology implementation. Again, three of the teachers were technologically proficient and were advocates for technology use in the classroom. Sharing expertise and time with fellow teachers built confidence in those less familiar or comfortable with the new classroom strategies.

van den Berg [12] noted that most teacher change is governed by a practicality ethic, explaining that teachers judge change proposals based on three components: instrumentality, congruence, and cost-benefit. Instrumentality pertains to the clarity of the plan and the ease of implementation. Congruence refers to how closely the proposed change is aligned with teachers' beliefs and values. Cost-benefit can be defined as the ratio of investment return. From a teacher's point of view, time, energy, and threat determine the cost. Benefits are derived from teacher satisfaction but more importantly, from apparent student learning and enthusiasm.

In fact, the project made trying the new strategies relatively easy: materials were either on-site or supplied, lessons were created with the help of project staff, and staff modeled the inquiry teaching approach. As teachers worked through inquiry activities themselves, one commented: "Why didn't we learn science like this? I might have liked it." Once teachers took the first step, and then student enthusiasm carried them further down the inquiry path. Once down the path, improved student behavior, increased participation, and better test scores help teachers stay the course toward an inquiry approach to teaching science.

When participants were asked to comment on the change effort, they consistently reiterated the components of van den Berg's practicality ethic: "Give me a good reason, show me it will work, and then give me the time to do it properly." One science teacher, Margaret, with 26 years experience commented: "Most teachers have no philosophy of why they do things. They do what's easiest or what they're told, in fear of the administration."

Don responded: "We need to know the philosophy behind it; not just hear 'do it'. Look how many canned programs fail. They fail because they skip the philosophical base. And why don't we know the philosophy? Because the attitude is 'You aren't smart enough to know this'."

Mundry and Loucks-Horsley [13] emphasized the need for professional development to maintain a balance between philosophical and pragmatic concerns while being responsive to teacher needs as well as the dynamic school context. They suggested that a program guided solely by practicality lacks vision for program improvement, while on the other hand, a program guided solely by philosophical issues ignores the day-to-day realities of teachers' lives.

Two teachers commented that they "read about it", when told to do something by the administration, and then decide what to do. Susan explained that when asked to change to a different textbook series one year, she conducted her own research. She ultimately refused and continued to use old books or no books to teach her students. Within two years, the county discarded the new texts.

The consensus was that "there's a new change always coming." And with that change, there comes little support. If Hodges [9] is correct and deep learning and change takes three to five years, then teachers require protracted administrative support over time. Yet those are the two items most lacking: support and time. If there was one word that appeared somewhere in every teacher's response it was "time".

Supporting Teacher Change

The science inquiry and technology professional development project indeed facilitated teacher change. Impediments to that change included insufficient administrative support as well as lack of resources and time. Although adhering to the guidelines of effective professional development, it is not sufficient to merely implement change. Such efforts must also provide the foundation for continuous and on-going follow-up and support.

Professional development efforts should look further than all the teachers of one discipline within a system. Rather, effective professional development must have continued,

system-wide support. Stein [14] suggested that professional development must be seen as everyone's job and everyone viewed themselves responsible not only for their own learning but also the learning of colleagues. Teacher training was not then, an isolated venue, but rather an integral part of everyday experiences within the system. This was the case in Ben Hill County, as illustrated by these comments:

> I don't have time to do everything they want me to this year: reading instruction, enrichment, five science classes, and half the planning time I had last year. Twice, no three times the work and half the planning time. And absolutely no resources. John, he's great. He brings me stuff, boxes of science stuff. He brings me demonstrations already set up. I can work with what he brings. And all of you, re-working the activities into the learning cycle format and making copies. I have the space to breathe. Maybe next term I'll have more time to try some new things on my own.

The study has shown that teachers can and will change they way they think about and do science. School districts must establish a climate for learning and environment that provides continued support for teacher change. To do this, professional development must grow from the district level, rather than just the department or school level, to encourage collaboration and mutuality. Although change must happen where work occurs, in the classroom, belief in and support for the change effort must be systemic.

Bios

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